DETERMINATION OF THE STEADY STATE AMPLITUDE AND FREQUENCY OF OSCILLATION IN ALMOST SINUSOIDAL NONLINEAR SYSTEMS

By

CHARLES V. JAKOWATZ

B.S., Kansas State College, 1944
M.S., Kansas State College, 1947

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IN THE GRADUATE COLLEGE OF THE
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It has been shown that the solution of a nonlinear triode associated with a linear network can be successfully carried out by assuming a power series solution for the network under consideration*. Certain assumptions must be made in regard to a vacuum tube acting as the nonlinear element, that is, constant amplification factor and no flow of grid current. In the case of oscillatory circuits this, in general, leads to a frequency-amplitude equation which may be solved provided the circuit constants are known and a suitable expansion of the voltage-current characteristics of the nonlinear device can be carried out. The solution of the frequency-amplitude equation may be difficult to carry out, especially, if a large number of harmonic amplitudes of oscillation are present. For the case of an almost sinusoidal oscillator with low second harmonic amplitude, it is not too difficult to find the magnitude of the third harmonic amplitude.

For the case of class A operation, the characteristics of the nonlinear device can be represented by means of a Taylor's series of the control voltage expanded about the quiescent operating point. If the bias is so chosen as to be beyond the cutoff value of the triode, the expansion in terms of a Taylor's series is no longer valid since the derivatives of the control voltage are discontinuous at the point of cutoff. However, if suitable piecewise expressions for the control voltage can be found, it is possible to obtain an approximation for the control voltage in the form of a continuous function in terms of a set of known orthogonal functions. A suitable expression for the control characteristic is given, and the solution of a tuned plate oscillator is carried out by an infinite series solution.

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* Gillies, A. W., "The Application of Power Series to the Solution of Nonlinear Circuits Problems," Proc. Insti. Elec. Engr., Vol. 96, Part IV, 1949.

Under certain conditions, the assumption of no grid current flow can be relaxed, provided that the grid circuit loss is small compared to the energy in the plate circuit, and that the distortion in the plate circuit due to grid voltage is neglected for all harmonics of the fundamental. This effect may be small compared to the distortion introduced as a result of the nonlinearity of triode. Grid distortion is accounted for by introducing a perfect diode in the grid circuit so as to govern the flow of grid current. To account for grid dissipation an equivalent resistive loading of the grid circuit is assumed. By considering the fundamental component of grid voltage, the analysis is then carried out neglecting the harmonic components of grid voltage.

For the particular case of a tuned-plate oscillator, a set of design curves [15] are given which enables one to determine the steady state amplitude of oscillation. These design curves are based upon a given resistive loading of the plate circuit, and can be used as long as the loading is not altered. The bias voltages under these conditions must be chosen so that the resistive load line passes through the bias point drawn on the plate characteristics of the nonlinear triode. Under these conditions one can specify the circuit parameters and bias voltages and obtain the steady state amplitude of oscillation. Since, in normal design, one usually specifies the transfer function of the feedback network, a preliminary calcuation is made to see what the relative magnitude of maximum grid voltage is. It the maximum value of grid voltage is greater than the bias voltage, a correction on the feedback function is made and a new value of amplitude is calculated. The agreement between calculated and measured amplitudes was found to be good for values where the coupling was somewhat greater than that necessary to set the circuit into oscillation. Poorer agreement when the circuit is set just at the verge of oscillation can be attributed to the precision with which one must be able to measure certain circuit parameters.

It is felt that the important case of class C operation of oscillators can be handled by means of the method outlined. Furthermore, since the amplitude of oscillation usually stabilizes with some flow of grid current, the correction for the effect of grid rectification, which can be treated approximately, seems to be valid in the case where the grid circuit loss is small compared to the energy of the plate circuit.

VITA

The author was born at Kansas City, Kansas on February 6, 1920. He attended Ward High School of that city from 1934 to 1938. After graduation he attended Finlay Engineering College, Kansas City, Missouri and received a B.E.E. from that institution. During the years 1940 to 1944, he attended Kansas State College, receiving a B.S. degree in Electrical Engineering in February, 1944. From February 1944 to July 1944, he was with the General Electric Company as a test engineer.

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During the period, September 1945 to September 1948, he was affiliated with Kansas State College as, graduate student, receiving an M.S. degree in Electrical Engineering in 1947; later, instructor in mathematics, and assistant professor of mechanical engineering. From September 1948 to September 1952, he was associated with the University of Illinois as instructor of electrical engineering, and at the present time is assistant professor of electrical engineering devoting one-half time to research work on the investigation of oscillatory circuits.

He is a member of Sigma Xi, Phi Kappa Phi, Pi Mu Epsilon, Eta Kappa Nu, Sigma Tau, American Society for Engineering Education, and an associate member of the Institute of Radio Engineers. He is co-author of a paper entitled "Downward Projection of Air", **Trans. A.S.H.V.E.**, Vol. 54, 1948.